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High quality decoding for PAL inputs to digital YUV studios

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Summary

With the planned conversion of studio equipment to digital component signal operation, there will be a requirement for high quality PAL decoders at the interface with current equipment. The addition of movement detection circuits to picture delay comb filters was expected to produce a decoder with good overall performance. However, movement detection methods have so far been unable to produce a satisfactory mode switching signal for the adaptive control. If this problem proves fundamental, an alternative non-adaptive approach will be needed in which the bandwidths of the luminance and chrominance output signals may have to be noticeably reduced. In this case, the positioning of decoders to minimise the number of decode and recode operations will be an important factor in maintaining reasonable quality from PAL signals during the changeover period to YUV.

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HIGH QUALITY DECODING FOR PAL INPUTS TO DIGITAL YUV STUDIOS

C.K.P. Clarke, B.Sc. (Eng.), A.C.G.I.

1. Introduction

The newly adopted digital standard based on 13.5 MHz line-locked sampling of luminance and colour difference signals (YUV components) can provide television pictures of very high quality. In addition, with signals in this form, quality can be maintained through many stages of processing. Therefore, the system can include all the complex facilities necessary in modern programme production and still present the home viewer with excellent pictures.

When conversion to the new system is complete, signals will remain in YUV form throughout the network and will only be encoded to composite form at the broadcast transmitter. However, over an interim period of many years, both systems will be in use. In this situation, some of the signals reaching component areas will already have been PAL encoded and will need to be decoded to mix with directly generated YUV signals. Conventional methods of PAL decoding, although capable of providing acceptable picture quality in home receivers, are not suitable for this application. This is because conventional decoders do not separate luminance and chrominance adequately, thus leaving cross-luminance (subcarrier dots) and cross-colour (luminance demodulated as chrominance) mixed in with the true component signals. In general, the presence of these cross-effects in the decoded pictures is not very noticeable and they have become accepted features of the colour television system. However, if the decoded signals are recoded to PAL, the cross-effects can produce different picture impairments. These are caused by the residual signals left from the first encoding process interfering with the signal produced by the second encoder. Moreover, the impairments can be exaggerated by the effect of processing between the decoder and the second encoder.

Some of these impairments are already noticeable on our screens, even before the general introduction of YUV equipment. This occurs because some equipment, although accepting PAL inputs and providing PAL outputs, operates internally on decoded YUV signals. For example, when certain picture effects are introduced, there is a noticeable loss of resolution which, in part, is due to the need for full suppression of the first subcarrier. Also, when a still frame is "grabbed" from a decoded PAL signal, the frozen residual subcarrier on edges beats with the normal subcarrier of the second encoder resulting in flicker at the edges of coloured areas.

The decoding process can be divided into two separate parts: the separation of luminance and chrominance signals and the demodulation of chrominance. In the demodulator, the use of digital techniques with line-locked sampling[1] has proved beneficial, resulting in stable, well defined performance with the convenience of digital outputs directly compatible with the YUV standard. However, the separation of luminance and chrominance remains a problem, because, although those methods of line-,[2] field-[3] and picture-based[4] comb filtering so far tried have proved adequate for most moving-image signals, there is a significant range of such signals for which the methods are unsuitable.

2. Luminance-Chrominance separation

In the PAL colour system, the subcarrier frequency is chosen to minimise its visibility. Therefore, besides being a high horizontal frequency (4.43 MHz), the subcarrier has phase offsets from one line to the next and from one picture to the next. It appears on the screen as a pattern with high vertical and temporal frequency components. It is this property of the subcarrier which is used in comb filters for separating chrominance and luminance.

Because of these phase offsets, the main chrominance and luminance components of a PAL signal are located in different parts of the vertical-temporal frequency spectrum, as shown in Fig. 1. The modulated U and V chrominance components are also offset from one another by the effect of the PAL switch. The luminance components are repeated around (± 25 Hz, ± 312½ cycles/picture height (c/p.h.)) by the effect of 625/50 interlaced scanning. Although the components shown in Fig. 1 do not overlap, luminance and chrominance components can, in practice, both extend throughout the spectrum, so that considerable overlap results for some pictures.

The effect of line-, field- and picture-delay comb filters for chrominance separation is shown diagrammatically in Fig. 2. In each case, the main chrominance energy is retained and the main luminance energy is rejected; nevertheless, some luminance signals enter the chrominance channel

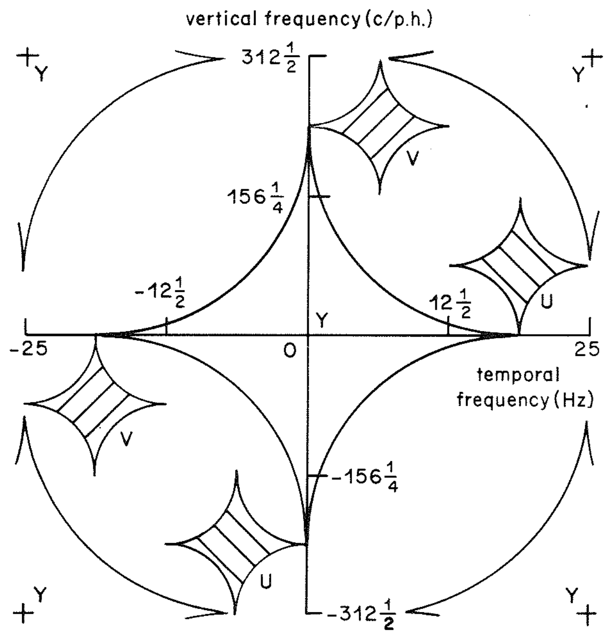

Fig. 1 - Relative positions of modulated U and V chrominance and high frequency luminance (Y) in the vertical-temporal frequency spectrum (shown for positive values of horizontal frequency).

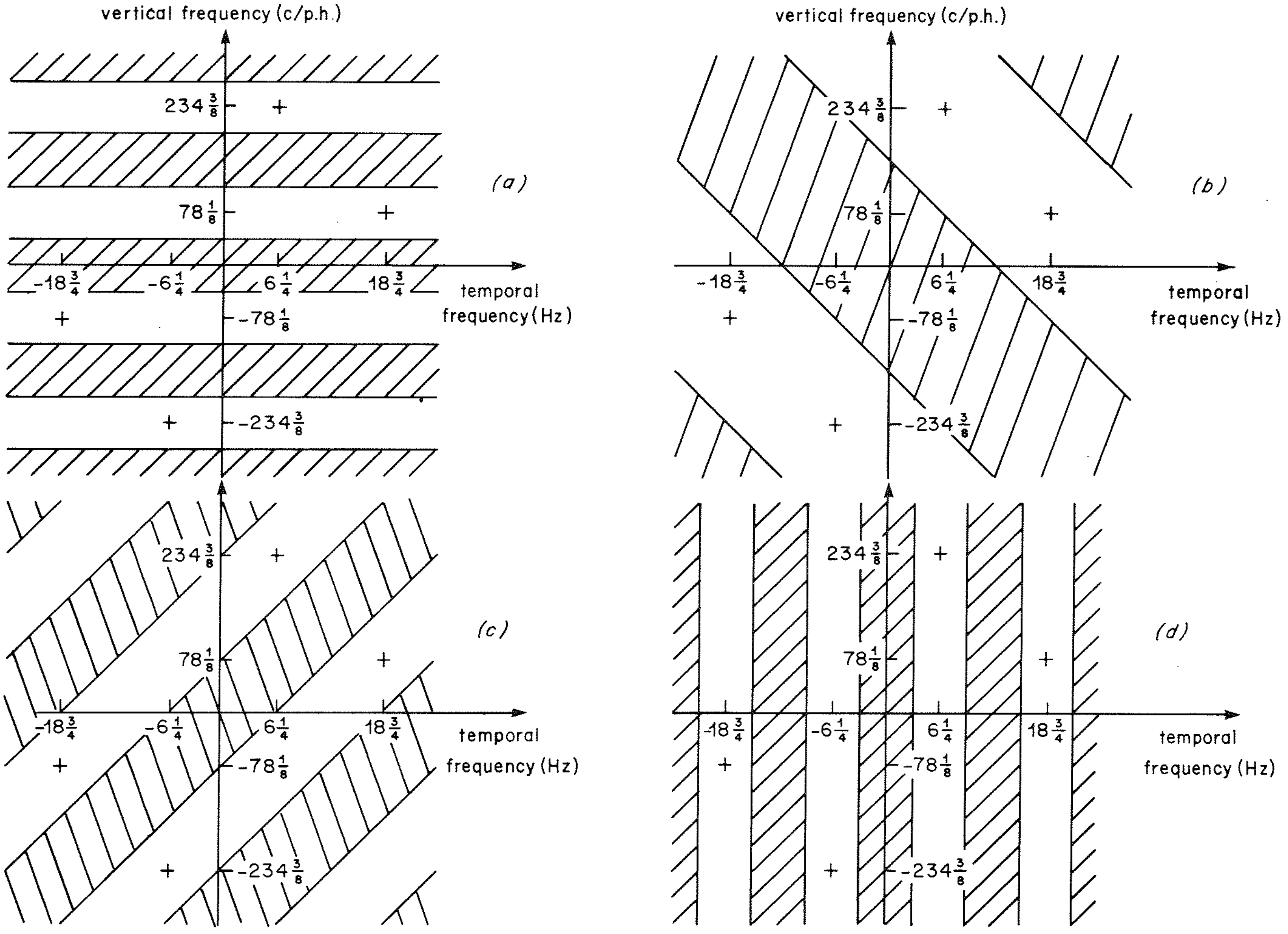

Fig. 2 - The vertical-temporal frequency characteristics of line-, field- and picture-delay comb filters for chrominance separation. Chrominance rejection is shown cross-hatched. (a) 1-line, (b) 312-line, (c) 313-line and (d) 625-line delays.

to cause cross-colour. Frequency characteristics complementrary to those of Fig. 2 can be used for separating high frequency luminance.

Of the characteristics in Fig. 2, the 312-line field delay method best exploits the relative positions of the luminance and chrominance energy centres. However, in picture signals, the energy tends to be concentrated along lines parallel to the axes. For example, with still pictures, all the signal energy is concentrated along lines parallel to the vertical frequency axis. So, under these conditions, the 625-line decoder will give perfect separation. However, impairments will occur when temporal frequency components are present, resulting from moving areas of picture. Fig. 3 shows comb filters using 312-line and 625-line delays.

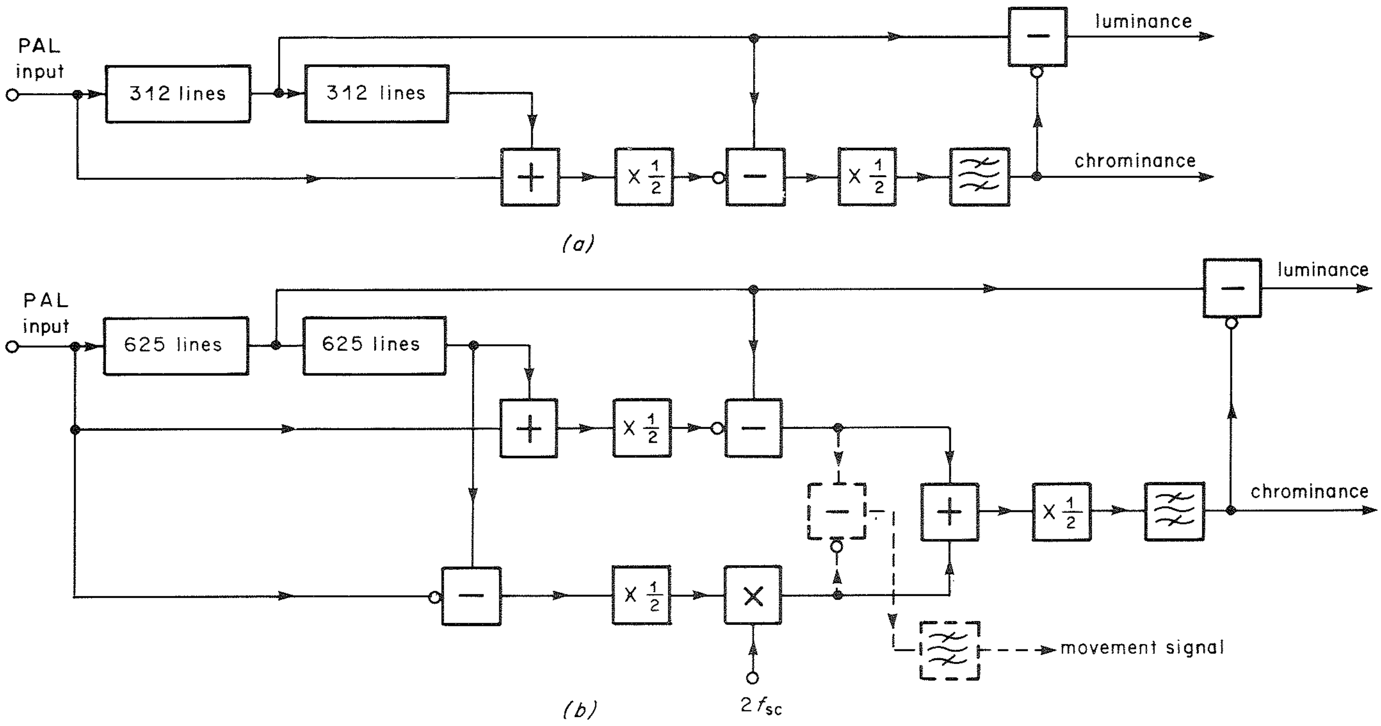

Fig. 3 - Comb filters for luminance and chrominance separation using (a) 312-line delays and (b) 625-line delays (Weston). Additional components for a movement detection signal are shown dashed in (b).

3. Movement-adaptive decoding

While the 312-line comb filter gives a good balance of low-level impairments, both still and moving areas of picture are impaired. In contrast, the 625-line comb filter is much better for still or slowly moving areas of picture, providing near perfect separation, but produces more serious impairments on rapid movement. Therefore, in principle, it would be possible to detect moving areas of picture and to change to a different comb filter (for example, based on one-line delays) to avoid movement impairments. This would combine the good still-picture performance of the picture-delay filter with the acceptable movement performance of the line-delay filter.

The detection of movement in PAL signals is complicated by the subcarrier itself being a moving pattern, even for still pictures. Thus, the movement detection circuit must have a temporal characteristic with zero response for stationary luminance and for both the modulated chrominance energy centre positions. A simple detection method can be provided by the addition of a subtractor to the circuit of Fig. 3(b) (shown dashed). For areas of picture containing no movement the two inputs to the subtractor are identical consisting of similarly phased chrominance and containing no luminance. With movement however, the signals differ both in chrominance and luminance content so that the subtractor produces an output to switch to an alternative, movement decoding mode.

The main impairments with the basic picture-delay filter of Fig. 3(b) occur when the pictures contain rapidly moving coloured objects.

Although these are detected by the subtractor circuit, moving areas of high frequency luminance predominate in many pictures and these also switch the decoder to the line-based movement mode. This is undesirable as it results in increased cross-colour. If differential phase distortion is present on the signal, the subtractor circuit produces an output for coloured areas in still pictures. In addition, the movement detector may be confused by the presence of noise in the signal.

Although the detection of moving chrominance can be improved by including extra chrominance bandpass and comb filters in the movement detector path, this does not completely solve these problems. For many signals, therefore, the decoder may remain in the line-based movement mode for the majority of the time. The same detection problems are likely to be met with other movement-adaptive decoding methods. Therefore, although adaptive decoding may achieve good results in test signals which are free from noise and distortion, and give well defined signals in the movement detector circuits, on practical signals the decoder may remain almost entirely in the poorer performance movement mode. The advantages of picture delay comb filtering for still pictures would then be lost.

Accepting that movement detection will be imperfect under some signal conditions, it is prudent to ensure that the overall performance of both the still and moving picture modes is reasonably good. For example, although using a wide chrominance bandwidth in the picture-delay decoder would improve still-picture performance, this would result in more cross-colour on moving pictures. Therefore, overall, a reduced chrominance bandwidth is to be preferred.

The complexity of adaptive methods needs to be carefully considered in relation to their benefits. Besides the extra circuitry required for movement detection, it is necessary to provide separate comb filter circuits for the still mode and the movement mode. If for either comb filter the luminance and chrominance circuits are non-complementary, this leads to an additional increase in complexity. Therefore, the circuitry required for an effective adaptive method may be up to three times that required for a non-adaptive decoder.

4. Decoding alternatives

In PAL decoding for use in YUV studios, it is the suppression of cross-effects, particularly cross-luminance, that is of primary importance rather than the appearance of the decoded pictures. This is because, when processed, recoded and decoded again in the home receiver, these cross-effects can cause considerably greater impairments than appear in the studio YUV signals. If, even after further development of movement detection techniques, adaptive decoding should still prove unsatisfactory, then the only course remaining is to accept decoded YUV signals of a noticeably lower specification than that of directly originated YUV signals. Thus, it may be necessary to ensure an adequate level of cross-luminance suppression by restricting all luminance signals in the decoder output to below 4 MHz and using comb filters further to restrict diagonal luminance resolution at 78 and 234 c/p.h. to perhaps 2.5 MHz. This will result in luminance almost completely free of residual subcarrier, but will produce noticeably softer pictures. Similarly, the use of vertical comb filtering to suppress Hanover bars and a narrow chrominance bandwidth (< 1 MHz) will greatly reduce cross-colour in the decoded signals, but some chrominance definition will be lost. Although softer, the pictures produced for the home viewer from such a decoder are likely to be preferable to those of higher definition with inadequate suppression of cross-effects. Also, such a decoder would be considerably simpler and cheaper than an adaptive decoder.

5. Positioning decoders in the television system

A necessary outcome of achieving greater suppression of cross-effects is that the complementary nature of chrominance and luminance filtering is lost. In a complementary decoder, all the input signal is preserved, either in the chrominance or the luminance channel. This is illustrated in Fig. 4(a) which shows that, if the separated chrominance and luminance signals are added together again, as would occur in a subsequent PAL coder, the original signal is reproduced (this assumes correct recoding phase). However, if the luminance and chrominance responses are both narrowed to achieve better suppression of cross-effects, the separated signals have irretrievably lost some information which results in gaps in the spectrum of the recombined signals, Fig. 4(b). These non-complementary decoders are therefore less likely to retain adequate performance through multiple decoding and recoding operations. This is because with practical filters, the spectrum gaps will broaden as the number of cascaded filters increases.

In view of this, it is more necessary to consider the positioning of decoders in the

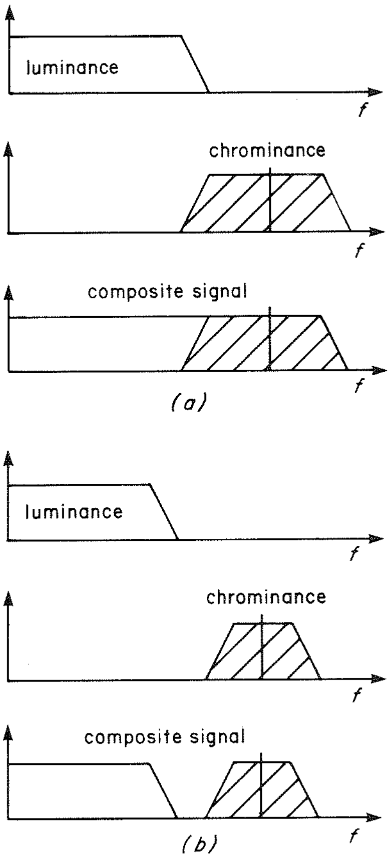

Fig. 4 - Spectra showing the effect of recombining separated luminance and chrominance signals in a coder (a) with complementary filters and (b) with non-complementary filters in the decoder.

television system with a view to minimising the number of decoding and recoding processes. For example, it would be unreasonable to include the less reversible, reduced definition decoder in a loop with a digital video tape recorder, as the resolution loss would be unacceptable after multiple generations. In contrast, the more reversible complementary decoders could give adequate performance in this situation because the DVTR loop would not normally include any significant signal processing to exacerbate the impairments

If digital YUV equipment is introduced by spreading initially from the signal origination equipment (cameras, telecines, etc) then no extra decode-recode processes are required. Also, YUV equipment can spread back from the broadcast transmitter; since the links would not alter the YUV component signals, it would be possible to phase-lock the PAL coder at the transmitter to a complementary PAL decoder at the studio and thus achieve no additional loss of quality at the home receiver. However, the introduction of most YUV equipment so far has been for post-production processing. Also, it is widely accepted that the development of YUV areas will centre around the introduction of digital video tape recorders. This approach tends to magnify the decoding problem.

As the conversion to component signals proceeds, the number of PAL sources will reduce. However, decoding to YUV will still be needed, even after the completion of the conversion to digital components systems, to provide access to the large amount of archival material in analogue PAL form.

6. Conclusion

The provision of high-quality PAL decoders is an essential element in the introduction of digital component systems. The arguments put forward above suggest that it will be difficult to find a movement detection technique that, on critical signals, can combine the performance of the best still-picture and moving-picture decoding methods. However, the search for a satisfactory movement-adaptive method should continue unless the problems with current movement detection techniques prove to be insoluble. In that case, a compromise, non-adaptive method would have to suffice. Decoding and recoding problems could be ameliorated by the careful positioning of decoders during the changeover to digital component signal operation.

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